

Emission of Cathode and X-rays by Celestial Bodies.¹

By Dr. HENRI DESLANDRES.

THE emission by the stars of X- and cathode rays and similar radiations has already been considered and investigated by various writers.² The two kinds of radiation, however—X- and cathodic—are not separable, for each, when it meets an obstacle, gives rise to the other, this interdependence having been clearly pointed out by de Broglie. But their properties are different: X-rays move in straight lines, and are much the more penetrating, while cathode rays are easily deflected into helical paths by a magnetic field—or, again, by an electric field. The paths of the electrified particles forming cathode rays, under the influence of a magnetic field like that of the earth, have been revealed by the detailed calculations of Störmer: they are very interesting, and much more varied than the trajectories due to gravitation.

I. In several notes, from 1896 to 1922,³ I have suggested the emission of cathode and X-rays by the sun, and also by the nuclei of nebulae. The rays of the solar corona can thus be explained, and also the aurora borealis and the magnetic disturbances of the earth, their connexion with sunspots, and even the lag of these disturbances behind the passage of a spot across the central meridian of the sun's disc—a lag due to the deviation imposed by the outer solar magnetic field. The same idea was put forward also in 1896 by Birkeland, who carried the investigation further: he was able to reproduce, in the laboratory, some of the phenomena of the aurora borealis by means of a small sphere placed in a vacuum, magnetised like the earth, and bombarded by cathode rays. Later, the researches, both theoretical and experimental, of Störmer made a great advance in the investigation, and placed almost completely beyond doubt the emission by the sun of ordinary cathode rays. In terms of these rays, Störmer explains the smallest details of the aurora borealis, so rich in singular phenomena. He has even been able to locate the origin of the rays in the sun, and to determine the value of the external solar magnetic field. This value, which is very small and equal to 10^{-7} gauss, is exactly that which I found in 1911 by another method depending on the radial velocities of the solar prominences recorded at Meudon.

The earth also emits these special radiations. The radio-active bodies in its solid crust and in its atmosphere emit α -, β -, and γ -rays, which ionise the atmospheric gases and explain partly the permanence of the terrestrial electric field. To explain the whole field, it must be assumed that there enter, from the outside, rays which are very penetrating—even more penetrating than any known X-rays. Further, if one ascends in the atmosphere—as did Kohlhörster, who reached a height of 9000 metres—the number of ions formed per

second in a closed chamber is found to increase rapidly; at 9000 metres it is eight times as great as at the surface of the earth. The amount of this penetrating radiation therefore increases rapidly with altitude. It proceeds probably from the sun, directly or indirectly, or even from cosmic space,⁴ but its exact origin has yet to be determined.

Such are the first results; they are extremely interesting, but still very incomplete. The investigation thus begun should be pursued with every means at our disposal.

II. Researches connected with the atmospheres of yellow stars, carried on at Meudon during 1922 with Burson, have led me to conclude that in these stars there is an extremely penetrating X-radiation, emitted by the interior strata or the nuclei of the stars. These results, which have been stated very briefly in former communications,⁵ are now given in detail.

The sun, which is a yellow dwarf star, shows, as is known, in its integrated spectrum,⁶ three groups of calcium lines— H_1 , K_1 ; H_2 , K_2 ; H_3 , K_3 —weak, but very distinct—which represent, respectively, the lower, middle, and upper strata of its gaseous atmosphere or chromosphere. Burson and I have discovered these lines—in particular, the lines H_2 , K_2 , H_3 , K_3 in several giant stars which are equally yellow. They have the peculiarity that the lines, when compared with the neighbouring continuous spectrum, are stronger and wider than in the spectrum of the sun. The middle and upper strata of the chromosphere are more luminous and important than the corresponding solar strata.

Stars of the two types, giant and dwarf, have at the surface, however, the same chemical composition, the same temperature, and the same surface brightness. How is the difference in the luminosities of their atmospheres to be explained?

The atmospheric strata are represented by the radiations H and K, which, as is now known with certainty, are emitted by the ionised atom of calcium. If, therefore, we consider, in each type of star, a tube normal to the surface, having unit cross-section and extending from the surface to the outer limits of the atmosphere, the brightness of each stratum in the tube will be proportional, or at least closely related, to the number of ions formed in it per second. The number of ions formed must therefore be greater in the giant stars. Now one of the principal causes of ionisation already pointed out is the intense emission of electrons by the

⁴ The earth also probably emits a very penetrating X-radiation—more penetrating than the γ -rays of radium: this has been suggested by some writers. But, if it exists, it is relatively weak, and it has not yet been clearly separated from the very penetrating X-radiation coming from external sources.

⁵ Sur la reconnaissance dans les étoiles des couches successives de leur atmosphère et des variations périodiques de ces couches (*Comptes rendus*, 171, p. 451, 1920, by Deslandres). Recherches sur l'atmosphère des étoiles, Reconnaissance d'étoiles qui ont les mêmes brillantes de l'atmosphère que le soleil (*Comptes rendus*, 172, p. 405, 1921); Recherches sur l'atmosphère des étoiles, Reconnaissance de la couche supérieure dans quelques étoiles et comparaison avec le soleil (*Comptes rendus*, 172, p. 479, 1921); Recherches sur l'atmosphère des étoiles, Propriétés des étoiles qui ont les mêmes radiations et les mêmes couches de la chromosphère que le soleil (*Comptes rendus*, 175, p. 121, 1922, by Deslandres and Burson).

Burson and I intend to publish shortly some new results. In particular, we have discovered that, in certain giant stars, the lines H_2 , K_2 of the upper stratum are displaced towards the red, and the lines H_3 , K_3 of the middle stratum are displaced towards the violet, as in the case of the sun.

⁶ The integrated spectrum is that which the sun would give if it were as far from us as the stars.

¹ Translation of a paper read before the Paris Academy of Sciences on October 2, 1922.

² X-rays are constituted like the γ -rays of radium, except that the latter have a greater frequency. The ultra X-rays, discussed in this note, have a still greater frequency. In the same way, β -rays resemble cathode rays. As for α - (positive or anode) rays, which play an important part in ionisation in general, they are absorbed very quickly, and move only a short distance from their origin.

³ *Comptes rendus*, 126, p. 1323, 1898; 134, pp. 1134 and 1486, 1902; 150, p. 65, 1910; 152, p. 1453, 1911; 155, p. 1573, 1912; 157, p. 517, 1913; 171, p. 451, 1920; 172, pp. 405 and 709, 1921; 175, p. 121, 1922. See also "Observations de l'Eclipsé totale de 1893" (Gauthier-Villars, 1899).

surface, produced, in the yellow stars, at a temperature of about $6000^{\circ}\text{C}.$; but the ionisation from this cause is the same in the two types of star. In order to explain the greater brightness of the giant stars, it is necessary to suppose that they contain another source of ionisation which is peculiar to them, or more important than it is in the dwarf stars. The principal supplementary cause appears to me to be a penetrating radiation emitted by the interior layers of the star; this radiation would be stronger in giant stars, which have greater masses, and therefore higher internal temperatures. In an example cited by Eddington⁷ the temperature at the centre reaches $4,650,000^{\circ}\text{C}.$, the mass being only one and a half times that of the sun. The wavelength of maximum energy for a black body at this temperature is $6\text{ \AA.U.}$ —corresponding to an X-ray near the ultra-violet, and not very penetrating; but, according to the theory, the radiation extends much further towards the very short wave-lengths, the penetration of which is much greater; and the intensity of these extreme radiations increases with the temperature of the star. The emission of exceptionally penetrating radiations by giant stars is therefore admissible. Further, in the case of giant stars which are in the phase of increasing temperature, the atoms are dissociated, and their breaking-up is accompanied by an intense emission of α -, β -, and γ -rays. It should be remarked that recently certain rays of radium have been observed, much more penetrating than any previously known, the source of which must be in the very nucleus of the atom.

In the yellow stars, all these radiations, of very high frequency and of great penetrating power, form, in reality, only a very small part of the total radiation; but their remarkable electrical properties assign to them an important rôle in the electrical phenomena of stellar atmospheres. It is not, however, intended to assert that the existence of the radiations is proved, but it is very probable. As a matter of fact, we have a very imperfect knowledge of the properties of the material in the interior of a star near the surface and in the atmosphere; and, as often happens in astronomy, the deductions rest on wide extrapolations. In forming conclusions, great care must be exercised.

There has been a great deal of discussion on the nature of the solar surface. In my opinion, setting aside every theory and every explanation, the solar surface is a simple fact of experience; it is a surface of discontinuity, with a clear-cut boundary, such that the light emitted by the interior is much more intense than that given by the exterior. I give the name "atmosphere" to all that is outside this surface. The word "surface," however, should not be understood strictly in its geometrical sense: it implies, actually, a relatively thin luminous stratum which, at our distance from it, appears to have no thickness. The solar surface has often been described as a cloud, made up of incandescent liquid or solid particles. If this were so, in all the yellow stars having the same temperature, whether giant or dwarf, the pressure of the gases at the surface should be the same; but it has been objected that we have no knowledge of any matter which remains liquid at a temperature of $6000^{\circ}\text{C}.$ The attractive optical theory of Schmidt also

has been advocated: when thoroughly examined, however, it is found not to be applicable to the sun. Let us say simply that, from a cause still imperfectly understood, solar matter, probably gaseous, acquires suddenly, in a stratum called the *surface*, the emissive power of a solid body, and there are good reasons for believing that the pressure of the gas in this stratum varies little from one yellow star to another, so long as the temperature of the strata is the same.⁸ These considerations support the idea of the very penetrating emission postulated in the giant stars.

III. These special rays, remarkable for their penetration and their electrical action, have been known or suspected only for a few years; but their importance is already declaring itself, and I think that they will furnish the key to several of the still numerous enigmas presented by the celestial bodies.

The matter of the sun, then, probably emits X-, ultra-X-, and corpuscular rays, with an intensity which increases from the surface to the centre. In the spots, which are in general cavities, the emission is strongest in the centre, and, because of its greater penetration, is able to persist in spite of local absorption and the diminution of the ordinary light. Similarly, if the earth gives rise to a radiation of this kind, its intensity should be greater at the poles than at the equator.

These radiations should be borne in mind especially in considering the nebulae—in particular, the gaseous and planetary nebulae. A nebula with a stellar nucleus may be considered as a star the atmosphere of which is extraordinarily developed and contains special gases, such as nebulium. The conditions are then, on a very large scale, those of the yellow giant stars examined above, the atmospheres of which are particularly bright; and the same causes may be held to account for the luminosity in the nebulous atmosphere. Moreover, the nucleus, being of the Wolf-Rayet type, is one of the hottest stars: it is conceivable that the maximum emission takes place, for the nucleus in the X-region, and for the nebula, properly so called, in the visible region. The luminosity is produced by radiations of very short wave-length, but with a habitual tendency towards longer wave-lengths. Lastly, the nucleus may contain a large proportion of radio-active bodies. These ideas were put forward in 1902, and Russell has recently developed similar hypotheses.⁹

If a nebula has no nucleus, we may suppose that there are radio-active bodies disseminated in the space which it occupies. Similarly, in the lower part of our atmosphere, a considerable fraction of the ions formed per second is due to the gaseous emanations of radium and rhodium spread abroad in the air. If there were a greater proportion of radio-active bodies, the gas might become luminous.

To sum up, the penetrating radiations are interesting in the highest degree, and it is important that we

⁸ If the pressure at the surface is less in the giant stars, the average density of which is smaller, we can explain partly the stronger ionisation in these stars by the very interesting theory of M. N. Saha. This theory deals with effects due to temperature alone, and the point of view is different. In a giant star the pressure gradient is evidently less steep, but the average pressure in the middle stratum, and especially in the upper stratum, may be very nearly the same as in a dwarf star. It should be noted that the greater proportion of the positive ions of calcium in the upper atmosphere may also be explained simply by the repulsion due to the positive charge on the star.

⁹ Deslandres, *Comptes rendus*, 134, pp. 1134 and 1486, 1902; Russell, *Proceedings of the U.S. National Academy of Sciences*, 5, No. 10, p. 410.

⁷ *Astrophysical Journal*, 48, pp. 205-214, 1918.

should study, immediately and as thoroughly as possible, those which are within our reach and are disclosed by Kohlhörster's experiment. The ionisation of gases in a sealed vessel has been measured in our atmosphere up to an altitude of 9000 metres; but it is necessary to repeat the experiment at several places on the earth, and to extend it up to the greatest altitudes reached in exploring balloons. The undertaking, it is true, will be costly; it devolves especially on the

countries which have the greatest resources. I proposed, at the International Astronomical Congress, which met at Rome in May last, that there should be international co-operation for the complete study of the electrical phenomena of our atmosphere at great altitudes. The determination of the exact origin of these penetrating radiations is one of the most important problems confronting physical astronomy at the present time.

The Desensitising of Silver Bromide-Gelatin Plates.

By Dr. T. SLATER PRICE.

IT is well known that the more sensitive a photographic plate is, the greater the care that has to be taken with respect to the actinic value of the light used in the dark room during the operation of development. The less the amount of light used, the more difficult it becomes to control the result; and it is therefore not to be wondered at that attempts have been made to modify the course of procedure in such a way that the exposed plate could be developed in a fairly good light. During the last few years various so-called "desensitisers" have been put on the market; when the exposed plate is either treated with a solution of these before development, or when some of the desensitiser is added to the developer, the plate can safely be developed in a light which would otherwise give rise to very bad fogging.

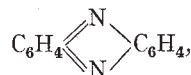
At the recent Deuxième Congrès de la Chimie Industrielle, M. A. Seyewetz gave an interesting account of the subject, and his paper has been published in *Chimie et Industrie*, 1922, 8, 308-311.

A. and L. Lumière and Seyewetz, in 1907, were the first to notice that a silver bromide-gelatin plate becomes less sensitive when bathed in a solution of a developer such as diaminophenol, quinol, or pyrogallol. The loss in sensitivity varied slightly in different regions of the spectrum, but was most marked in the yellow and green. At a much later date, in 1920, Lüppo-Cramer noticed that the desensitising action was much increased when sulphite was omitted from the developing solution, that is, when the developer was used in such a condition that it readily oxidised in the air. After immersion for a minute in a 0.05 per cent. solution of the developer the plate could be developed in yellow light without fogging. Such a method of desensitisation was insufficient, however, for orthochromatic and panchromatic plates, and moreover, the solutions underwent rapid alteration in the absence of sulphite.

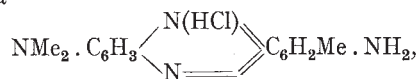
Desensitisation only became a practical proposition when Lüppo-Cramer, in 1921, discovered the pronounced desensitising action of the azine dye, Phenosafranine, and also of other dyes belonging to the same class, on ordinary and panchromatic plates. Contrary to what one would at first suppose to be the case, these dyes do not owe their action to functioning as colour screens; solutions of Phenosafranine transmit red and violet light, and yet they desensitise plates for these regions of the spectrum. Also, the violet safranines desensitise just as do the red safranines, although their absorption spectra are very different. These facts are very similar to those observed with sensitisers, and

Lüppo-Cramer has shown that certain optical sensitisers for one haloid salt of silver may act as desensitisers for other salts. For example, Erythrosin, Rhodamine B, Pinachrome, and Pinacyanol, which are the best sensitisers for chloride and bromide of silver, when used in very dilute solutions (1:20000) diminish the sensitivity of silver iodide-gelatin plates from 6 to 16 times; Phenosafranine gives a reduction in sensitivity of about 40 times.

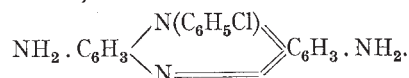
Lumière and Seyewetz have made investigations to see if there is any relation between the desensitising power of a substance and its chemical constitution. They have found, with the safranines, that the presence of the characteristic phenazine grouping,



is insufficient in itself, and that amino-groups substituted in the benzene nuclei must also be present. Thus Neutral Red, which is a Eurhoidine having the formula



has desensitising properties approximating to those of Phenosafranine, which is



Safranines in which one of the amino-groups has been eliminated, as in aposafranine, or in which this group is replaced by oxygen, as in the safranones, are notably less active as desensitisers. If both of the amino-groups are replaced by O or OH, as in safranin, there is no longer any desensitising action. The acetylation of the amino-group, or its diazotisation and copulation with a phenol, destroys the desensitising properties of the safranine, while the replacement by ethyl of the phenyl group attached to the nitrogen has no effect. The Indulines, which are near cousins to the safranines, as also the thiazines and the oxazines, do not act as desensitisers. On the other hand, other colouring matters which have very different constitutions from that of safranine as, for example, picric acid, Indian Yellow, Chrysoidine, etc., are weak desensitisers; Aurantia (1:1000) desensitises as actively as safranine for the blue rays, but is noticeably less active towards other parts of the spectrum.

It follows from the above that there does not seem